

**IRRIGATION PROBE FOR ABLATION
DURING OPEN HEART SURGERY**

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of U.S. Application No. 09/692,494, filed October 19, 2000, entitled IRRIGATION PROBE FOR ABLATION DURING OPEN HEART SURGERY, which is a continuation-in-part of U.S. Application No. 09/370,601, filed August 10, 1999, the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention is directed to an irrigation ablation probe for use during open heart surgery.

BACKGROUND OF THE INVENTION

Atrial fibrillation is a common sustained cardiac arrhythmia and a major cause of stroke. This condition is perpetuated by reentrant wavelets propagating in an abnormal atrial-tissue substrate. Various approaches have been developed to interrupt wavelets, including surgical or catheter-mediated atriotomy. It is believed that to treat atrial fibrillation by radio-frequency ablation using a catheter, continuous linear lesions must be formed to segment the heart tissue. By segmenting the heart tissue, no electrical activity can be transmitted from one segment to another. Preferably, the segments are made too small to be able to sustain the fibrillatory process.

It has been found that over 60% of patients with mitral valve problems also have atrial fibrillation. Moreover, patients undergoing open heart surgery commonly develop atrial fibrillation during the surgery, and thus it would be useful to address this problem during the surgery. Accordingly, under certain circumstances it may be desirable to treat atrial fibrillation during open heart surgery, for example, when a patient is undergoing a mitral valve replacement or repair procedure. Accordingly, a need exists for devices and methods for treating atrial fibrillation during open heart surgery.

SUMMARY OF THE INVENTION

The present invention is directed to an irrigation probe particularly useful for treating atrial fibrillation during open heart surgery. The probe of the present invention is also useful for other ablation and mapping procedures, particularly where irrigation of the ablation site is desired, such as for treating ventricular tachycardia. The invention is also directed to novel methods for treating atrial fibrillation with the probe of the invention. In accordance with the present invention, the probe comprises a rigid probe body and an irrigation electrode, which provides cooling and irrigation in the region of the tissue being ablated.

In one embodiment, the invention is directed to an irrigation ablation probe comprising a generally rigid probe body having proximal and distal ends. The probe body has an electrode at its distal end defining an inner cavity and having at least one irrigation opening through which fluid can pass and means for introducing fluid into the inner cavity. In a preferred embodiment, an infusion tube having proximal and distal ends is in fluid communication with the inner cavity. In another preferred embodiment, the infusion tube extends through the probe body for introducing fluid into the inner cavity of the electrode. In yet another preferred embodiment, the electrode comprises an elongated body having first and second ends, which is fixedly attached, either directly or indirectly, to the distal end of the rigid probe body at a point along the elongated electrode body between its ends, wherein the angle formed between the distal end of the probe body and the electrode is greater than 0° . In still another embodiment, the electrode is attached generally perpendicular to the distal end of the rigid probe body and has at least three irrigation openings through which fluid can pass. In still yet another preferred embodiment the electrode comprises a flexible metal ribbon coiled around the outside of a looped irrigation tube fixedly attached, either directly or indirectly, to the distal end of the rigid probe body, where the irrigation tube has irrigation openings through which fluid can pass to the electrode and wherein the spaces between the coils provide openings through which fluid can pass to the outside of the irrigation probe.

In another embodiment, the invention is directed to an irrigation ablation probe. The probe comprises a generally rigid probe body as described above and a handle. The handle is mounted to the proximal end of the probe body. In a preferred embodiment, the generally rigid probe body comprises a tubular body, an elongated electrode having first and second ends

1 mounted to the distal end of the rigid probe body at a point along the elongated electrode body
between its ends, wherein the angle formed between the distal end of the probe body and the
electrode is greater than 0° , and a non-conductive sheath covering the length of the probe body.
In still yet another embodiment the electrode comprises a flexible metal ribbon coiled around the
5 outside of a looped irrigation tube fixedly attached either directly or indirectly to the distal end of
the rigid probe body, where the irrigation tube has irrigation openings through which fluid can
pass to the electrode and wherein the space between the coils provide openings through which
fluid can pass to the outside of the irrigation probe.

In another preferred embodiment, the generally rigid probe body comprises tubing having
10 proximal and distal ends and at least one lumen extending therethrough. An electrode as
described above is mounted at the distal end of the tubing. The electrode has at least one
irrigation opening through which fluid can pass. The probe body further comprises means for
introducing fluid through the irrigation opening(s) of the electrode and a stiffening wire
extending through a lumen of the tubing. A preferred means for introducing fluid comprises an
15 infusion tube that extends through a lumen of the tubing with the distal end of the infusion tube
in fluid communication with the at least one irrigation opening in the electrode. In one
embodiment, an elongated electrode having first and second ends is mounted to the distal end of
the rigid probe body at a point along the elongated electrode body between its ends, wherein the
angle formed between the distal end of the probe body and the electrode is greater than 0° . In a
20 preferred embodiment the electrode is fixedly attached, either directly or indirectly, generally
perpendicular to the rigid probe body and has at least three irrigation openings through which
fluid can pass. In another preferred embodiment, the electrode comprises a flexible metal ribbon
coiled around the outside of a looped irrigation tube fixedly attached either directly or indirectly
to the distal end of the rigid probe body, where the irrigation tube has irrigation openings through
25 which fluid can pass to the electrode and wherein the space between the coils provide opening
through which fluid can pass to the outside of the irrigation probe.

In still another embodiment, the invention is directed to a method for treating atrial
fibrillation in a patient. The method comprises opening the heart of the patient and ablating at
least one linear lesion in the heart tissue using an irrigation probe as described above.

1 DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will be better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

- 5 FIG. 1 is a side view of an irrigation probe according to the invention;
 FIG. 2 is a side cross-sectional view of the handle of the irrigation probe of FIG. 1;
 FIG. 3 is a perspective view of the distal end of the T-shaped irrigation probe of FIG. 1;
 FIG. 4 is a side view of an alternative embodiment of an irrigation probe according to the invention;
 10 FIG. 5 is a side cross-sectional view of the distal end of the flexible metal ribbon irrigation probe of FIG. 4, wherein the rigid probe body comprises at least one lumen;
 FIG. 6 is an end cross-sectional view of the distal end of the flexible metal ribbon irrigation probe of FIG. 4;
 FIG. 7 is a side view of an alternative embodiment of an irrigation probe according to the
 15 invention; and
 FIG. 8 is a perspective view of the distal end of the flexible metal ribbon irrigation probe of FIG. 7.

DETAILED DESCRIPTION

- 20 The present invention is directed to an irrigation probe for use during open heart surgery. In one embodiment, as shown in FIGs. 1 and 2, the irrigation probe **10** comprises a probe body **12** mounted to a handle **14**. the probe body **12** comprises a tubular body **16**, having proximal and distal ends, covered over by a non-conductive covering or sheath **18** along its length and an electrode **19** mounted at the distal end of the tubular body. The electrode **19** is a generally
 25 hollow tubular structure having two ends **20** and defining an inner cavity therein. The electrode **19** is generally perpendicular to the tubular body **16** and fixedly attached to the tubular body **16** at a point between the two ends **20** of the electrode. The junction of the tubular body **16** and the electrode **19** forms an angle α that is greater than 0° , preferably greater than 10° , more preferably greater than 20° , even more preferably ranging from 70° to 110° , still more preferably ranging
 30 from 85° to 95° . Still more preferably, the electrode is fixedly attached at an angle α of about

1 90° relative to the distal end of the probe body, thus forming a generally T-shaped arrangement. The tubular body **16** extends the entire length of the probe body **12**, with the proximal end of the tubular body extending into the handle **14** as described in more detail below. The probe body **12** preferably has a length (from the distal end of the handle to the distal end of the probe body)
5 ranging from about 3.5 inches to about 12 inches, more preferably from about 5 to about 10 inches, still more preferably from about 7 to about 8 inches.

The tubular body **16** and the electrode **19** are both made of a material that is generally rigid so that the probe body **12** cannot bend during ablation, such as, for example, stainless steel (preferably 304VSS) or nitinol. Preferably the tubular body **16** and the electrode **19** have an
10 inner diameter ranging from about 0.40 inch to about 0.90 inch, more preferably about 0.047 inch, and an outer diameter ranging from about 0.50 inch to about 0.90 inch, more preferably about 0.059 inch. If desire, the tubular body **16** and/or the electrode **19** can be heat-treated so that they are malleable enough to be bent by a physician to a desired shape but still rigid enough that they will not bend in use during a procedure. For example, for 304VSS stainless steel, the material is
15 heated to about 800°F with electrical current or in a salt bath. The hollow interior of the tubular body **16** forms a lumen through which saline and the like may be conducted to the inner cavity of the electrode **19** by a separate external tube or the like.

The non-conductive sheath **18** extends from a proximal end inside the handle **14** to a distal end at a union of the tubular body **16** and the electrode **19**. The sheath **18** can be made of
20 any suitable biocompatible non-conductive material, such as polyurethane. In this arrangement, the electrode is exposed, i.e., not covered by the sheath **18**, for ablating tissue, mapping, etc. Preferably, the length of the electrode **19** ranges from about 0.50 inch to about 1.5 inches, more preferably from about 0.75 inch to about 1.25 inches.

In the depicted embodiment, the length of the probe body **12** is approximately 7 inches.
25 The proximal section of the probe body **12**, i.e., the portion extending from the handle **14**, is approximately 5.5 inches. The length of the electrode **19**, is approximately 1 inch.

As shown in detail in FIG. 3, the electrode **19** has a series of irrigation openings **21** for passage of a cooling fluid out through the inner cavity of the electrode **19**. The irrigation openings **21** can take any suitable shape, such as rectangular or oval slots or round holes. In a
30 preferred embodiment the electrode **19** has at least three irrigation openings **21**. the irrigation

1 openings **21** are preferably in the section of the electrode **19** that is to be in contact with the tissue during a procedure, e.g., to enhance the cooling of an ablation site.

Saline or other suitable fluid is introduced into the inner cavity of the electrode **19** through any suitable means. In the embodiment of FIGs. 1 to 3, fluids are introduced into the inner cavity of the electrode **19** via the tubular body **16** through a luer hub **22** or the like at the proximal end of the probe **10**. The luer hub **22** is connected to a flexible plastic tubing **24**, e.g., made of polyimide. The plastic tubing **24** is attached, either directly or indirectly, to the proximal end of the tubular body **16**, preferably within the handle **14**, as shown in FIG. 2. Alternatively, the tubing **24** can be connected to a suction source (not shown) to permit aspiration of fluid from the region of tissue being operated on.

As shown in FIG. 2, the handle **14** comprises a housing **26** having a generally open interior **28**. the tubular body **16** and sheath **18** extend into the distal end of the handle housing **26**. In the depicted embodiment, the sheath **18** terminated a short distance proximal to the distal end of the housing **26**. the tubular body **16** continues proximally beyond the sheath **18**. The flexible plastic tubing **24** extends into the proximal end of the handle housing **26**. The plastic tubing **24** is attached to the tubular body **16** within the open interior **28** of the handle, preferably at a point proximal to the proximal end of the sheath **18**. The plastic tubing **24** can be attached to the tubular body **16** by any suitable means, for example, polyurethane glue. By this design, cooling fluid is introduced through the luer hub **22**, thorough the plastic tubing **24**, through the tubular body **16** and out the irrigation opening **21** in the electrode **19**.

Alternatively, fluid could be supplied to the electrode **19** and thereby the irrigation openings **21** via a separate irrigation tube (not shown) that can either run external to the tubular body **16** and attach directly to the electrode **19**, or can extend through the tubular body **16** to the electrode **19**. In either case, this separate irrigation tube could be made of any suitable material, e.g., plastic or metal, and attach to the electrode **19** by any direct or indirect means.

An electrode lead wire **30** having proximal and distal ends is electrically connected at or adjacent its distal end to the probe body **16**. The proximal end of the lead wire **30** is attached to a connector **32** for connection to a suitable source of ablation energy, e.g., radio-frequency energy, or to an appropriate monitor. In the depicted embodiment, the lead wire **30** extends into the proximal end of the handle housing **26**. Within the open interior **28** of the handle **14**, the distal

1 end of the lead wire **30** is wrapped around the portion of the tubular body **16** not covered by the sheath **18** and held in place by solder or the like. The portion of the lead wire **30** that extends outside the handle **14** is covered by a flexible plastic protective tubing **34**, e.g., made of polyimide.

5 An alternative embodiment of an irrigation probe according to the invention is shown in FIGs. 4 to 6. As shown in FIG. 4, the probe **10** comprises a probe body **12** and a handle **14**. The probe body **12** comprises a non-conductive tubing **40** having proximal and distal ends. In a particularly preferred embodiment, the non-conductive tubing **40** comprises outer and inner plastic walls, e.g., of polyurethane or polyimide, surrounding an imbedded braided mesh of
10 stainless steel or the like. Preferably the tubing has an outer diameter or less than 8 French, more preferably less than 7 French. The tubing **40** has three lumens **42**, **44** and **46** extending along its length.

The irrigation probe comprises a metal ribbon electrode **47** at the distal end **48** of the non-conducting tube **40** comprising an exposed metallic ribbon **49** that is coiled around a loop of
15 irrigation tubing **56**, both of which are indirectly or directly fixedly attached to the distal end **48** of the non-conducting tube **40**. as illustrated in FIG. 5, the probe's distal end **48** is generally solid, having a fluid passage **50**, a first blind hole (not shown) and a second blind hole **54** that correspond in size and location to the three lumens **46**, **42**, and **44**, respectively, in the non-conductive tubing **40**. In the embodiment shown, the fluid passage **50** is in fluid communication
20 with the inner cavity of the flexible irrigation tube **56**, which extends from the distal end of the fluid carrying lumen **46** out of the probes distal end **48**. The irrigation tube **56** has a series of irrigation openings **57** for passage of a cooling fluid out through the spaces between the coils of the metallic ribbon **49**, as described in more detail below. The irrigation openings **57** can take any suitable shape such as rectangular or oval slots or round holes. In a preferred embodiment, the
25 irrigation tubing **56** has at least three irrigation openings **57**. The irrigation openings **57** are preferably in the section of the irrigation tubing **56** corresponding to the section of the metal ribbon electrode **47** that is to be in contact with the tissue during an ablation procedure to enhance the cooling to the ablation site.

The metallic ribbon **49** is coiled loosely around the irrigation tube **56** such that fluid can
30 pass unimpeded to the outside of the metal ribbon electrode **47**. the metal ribbon electrode **47**, as

1 shown in detail in Fig. 5, comprises a continuous ribbon **49** or conducting metal, extending
outside of the probe's distal end **48** and coiled about the flexible irrigation tube **56** in a loop,
having a radius ranging from about 0.5 inch to 1.5 inches. The metal ribbon **49** can be coiled in
any manner wherein the coils of the metal ribbon define an inner tubular passage through which
5 the irrigation tube **56** runs and wherein the coils of metal ribbon **49** are generally spaced
sufficiently far apart to allow fluid to escape through the irrigation passages. In a preferred
embodiment, the metal ribbon electrode **49** is coiled around from 1% to 100% of the length of
the irrigation tube **56** that is outside the probe body **12**. More preferably, the metal ribbon **49** is
coiled around from 20% to 80% of the length of the irrigation tube **56**, still more preferably the
10 metal ribbon is coiled around from 40% to 60% of the length of the irrigation tube **56**. the metal
ribbon **49** can be made of any suitable material, and is preferably machined from a 0.005 inch
thick ribbon of nitinol.

The metal ribbon **49** and the irrigation tube **56** can be attached to the probe's distal end **48**
in any suitable manner. In the depicted embodiment, the metal ribbon **49** and the irrigation tube
15 **56** are each attached at both ends to the probe's distal end **48** by a polyurethane glue seal **58** or
the like. However, any other means for fixedly mounting the metal ribbon **49** and the irrigation
tube **56** on the probe's distal end **48** can also be used. For example, only one end of the metal
ribbon **49** and/or the irrigation tube **56** may be attached to the probe's distal end **48**.

The metal ribbon electrode **47** is connected to a lead wire **67** having proximal and distal
20 ends. The proximal end of the lead wire **67** for the metal ribbon electrode **47** extends through the
third lumen **46** of tubing **40** and through the handle **14**. The distal end of the lead wire **67** for the
metal ribbon electrode **47** extends through the third lumen **46** and is attached to the metal ribbon
electrode **47** by any conventional technique, for example, by soldering.

In the embodiment shown, a mapping ring electrode **62** is mounted on the tubing **40**
25 proximal to the probe's distal end **48**. It is understood that the presence and number of ring
electrodes may vary as desired. The ring electrode **62** is slid over the tubing **40** and fixed in
place by glue or the like. The ring electrode **62** can be made of any suitable material, and is
preferably machined from platinum-iridium bar (90% platinum/10% iridium).

The ring electrode **62** is connected to a lead wire **64** having proximal and distal ends.
30 The proximal end of the lead wire **64** for the ring electrode **62** extends through the first lumen **42**

1 of tubing **40** and through the handle **14**. the lead wire **64** can be connected to the ring electrode
62 by any conventional technique. Connection of the lead wire **64** to the ring electrode **62** is
preferably accomplished by first making a small hole through the tubing **40**. such a hole can be
created, for example, by inserting a needle through the tubing **40** and heating the needle
5 sufficiently to form a permanent hole. The led wire **64** is then drawn through the hole using a
microhook or the like. The ends of the ring electrode lead wire **64** are then stripped of any
coating and soldered or welded to the underside of the ring electrode **62**, which is then slid into
position over the hole and fixed in place with polyurethane glue or the like. Any other means for
fixedly mounting the ring electrode **62** to the tubing **40** can also be used.

10 Both lead wires **64** and **67** terminate at their proximal end in a connector **32** that may be
plugged into an appropriate monitor and/or source of radio-frequency or other ablation energy.
The portion of the lead wires **64** and **67** extending out the proximal end of the handle **14** are
enclosed within a protective tubing **34**, which can be made of any suitable material, preferably
polyimide, as shown in FIG. 4.

15 An infusion tube **72** is provided for infusing fluids, e.g., saline, to cool the metal ribbon
electrode **47** during ablation. the infusion tube **72** may also be used to infuse drugs to the
ablation site. The infusion tube **72** may be made of any suitable material, and is preferably made
of polyimide tubing. The infusion tube **72** has proximal and distal ends, with its distal end
mounted in the fluid passage **50** of the probe's distal end **48** by any suitable method, e.g., by
20 polyurethane glue or the like. The infusion tube **72** extends from the probe's distal end **48**,
through the third lumen **46** of the tubing **40**, and through the handle **14**. as would be recognized
by one skilled in the art, the distal end of the infusion tube **72** can be positioned at any point
within the third lumen **46**. the proximal end of the infusion tube **72** ends in a luer hub **22** or the
like. Any other means for infusing fluids to the metal ribbon electrode **47** can also be used,
25 including running the infusion tube **72** external to the tubing **40** and fluid passage **50**.

A stiffening wire **74**, having proximal and distal ends, is mounted in the second lumen **44**
of the tubing **40**. the stiffening wire **74** is made of a rigid metal or plastic material, preferably
stainless steel, to prevent the probe body **12** from bending during a procedure. If desired, the
stiffening wire **74** can be heat-treated so that it is malleable and can be bent to a desired shape
30 before use, but still rigid enough that it will not bend in use during a procedure. A non-

1 conductive tube **76**, preferably made of polyimide, is attached to the distal end of the stiffening
wire **74** for mounting the stiffening wire in the probe's distal end **48**. the non-conductive tube **76**
extends out of the second lumen **44** and into the second blind hole **54** in the probe's distal end **48**,
and is secured in place by polyurethane glue or the like. Any other means for securing the
5 stiffening wire **74** within the probe can also be used. The proximal end of the stiffening wire **74**
terminates in the handle **14** or near the proximal end of the probe body **12**.

While FIGs. 4 to 6 depict an irrigation probe **10** having a metal ribbon electrode **47**, it
will be understood that the irrigation probe **10** described above and illustrated in FIGs. 4 to 6
could also house the generally T-shaped electrode **19** illustrated in FIGs. 1 to 3. In this
10 embodiment the generally T-shaped electrode **19** is fixedly attached, either directly or indirectly,
to the probe's distal end **48** such that the fluid passage **50** is in fluid communication with the
inner cavity of the generally T-shaped electrode **19**. The construction and function of the lumens
42, **44** and **46**, and the remainder of the probe **10** would be similar to that described above and
shown in FIGs. 4 to 6.

15 In another embodiment, as shown in FIGs. 7 and 8, the irrigation probe **10** comprises a
probe body **12** mounted to a handle **14**, which is described in detail above. The probe body **12**
comprises a tubular body **16**, having proximal and distal ends, covered over by a non-conductive
covering or sheath **18**. In this embodiment, a metal ribbon electrode **35** comprising a coiled
metal ribbon **33** and a loop of flexible irrigation tube **36** is disposed at the distal end of the probe
20 body **12** and fixedly attached, either directly or indirectly, to the distal end of the tubular body
16. The probe body **12** preferably has a length (from the distal end of the handle to the distal end
of the probe body) ranging from about 3.5 inches to about 12 inches, more preferably from about
5 inches to about 10 inches, still more preferably from about 7 inches to about 8 inches.

The tubular body **16** is made of a material that is generally rigid so that the probe body **12**
25 cannot bend during ablation, such as , for example, stainless steel (preferably 304VSS) or nitinol.
Preferably the tubular body **16** has an inner diameter ranging from about 0.40 inch to about 0.80
inch, more preferably about 0.047 inch, and an outer diameter ranging from about 0.50 inch to
about 0.90 inch, more preferably about 0.059 inch. If desired, the tubular body **16** can be heat-
treated so that it is malleable enough to be bent by a physician to a desired shape but still rigid
30 enough that it will not bend in use during an ablation procedure. The hollow interior of the

1 tubular body **16** forms a lumen through which saline and the like may be conducted to the
irrigation tube **36** of the metal ribbon electrode **35** and from there infused during an ablation
procedure, as described in more detail below. Alternatively, the tubular body **16** could be solid,
in which case fluids could be introduced into the irrigation tube **36** via a separate external tube or
5 the like.

The non-conductive sheath **18** extends from the proximal ends of the tubular body **16**
inside the handle **14** to the distal end of the tubular body at the union of the tubular body **16** and
the metal ribbon electrode **35**. The sheath **18** can be made of any suitable biocompatible non-
conductive material, such as polyurethane. Preferably the diameter of the loop of the metal ribbon
10 electrode **35** ranges from about 0.50 inch to 1.5 inches, more preferably from about 0.75 inch to
about 1.25 inches.

In the depicted embodiment, the length of the probe body **12** is approximately 7 inches.
The proximal section of the probe body **12**, i.e., the portion extending from the handle **14**, is
approximately 5.5 inches. The diameter of the loop of the metal ribbon electrode **35** is
15 approximately 1 inch.

As shown in detail in FIG. 8, the metal ribbon electrode **35** comprises an irrigation tube **36**
having first and second ends **37**, at least one of which is fixedly attached either directly or
indirectly to the tubular body **16**, similar to the embodiment depicted in FIGs. 4 to 6. the
irrigation tube **36** is bent so as to form a loop and the metal ribbon **33** is in turn coiled around the
20 irrigation tube **36** and fixedly attached, either directly or indirectly, to the tubular body **16**. In
one preferred embodiment, the metal ribbon **33** and irrigation tube **36** are both attached to the
tubular body **16** at both ends by any direct or indirect means, e.g., via a glue seal **38** as shown
above in FIG. 5. Any other means for attaching the metal ribbon **33** and the irrigation tube **36**
can also be used.

25 As shown, the irrigation tube **36** has a series of irrigation openings **39** for passage of a
cooling fluid out through the metal ribbon **33**. the irrigation openings **39** can take any suitable
shape, such as rectangular or oval slots or round holes. In a preferred embodiment, shown in
FIG. 8, the irrigation tube **36** has at least three irrigation openings **39**. the irrigation openings **39**
are preferably in the section of the irrigation tube **36** corresponding to the section of the metal
30 ribbon **33** that is to be in contact with the tissue during a procedure, e.g., to enhance the cooling

1 of the ablation site. The metal ribbon **33** is coiled loosely around the irrigation tube **36** such that fluid can pass unimpeded through the metal ribbon **33**.

Saline or other suitable fluid is introduced into the tubular body **16** through a luer hub **22** or the like at the proximal end of the probe **10**. the luer hub **22** is connected to a flexible plastic
5 tubing **24**, e.g., made of polyimide. The plastic tubing **24** is attached, either directly or indirectly, to the proximal end of the tubular body **16**, preferably within the handle **14**, as shown in FIG 7. By this design, cooling fluid is introduced through the luer hub **22**, through the plastic tubing **24**, through the tubular body **16**, through the first and second ends **37** of the irrigation tube **36** and out the irrigation openings **39**.

10 The irrigation probe shown in various embodiments in FIGs. 1 to 8, having either a metal ribbon electrode or a generally T-shaped electrode, can be used in any manner in which a standard probe can be used. For example, the above described probes can be used during open heart surgery for ablation. During an ablation procedure, the heart is opened and the irrigated electrode is used to form continuous linear lesions by ablation. As used herein, a linear lesion
15 refers to any lesion, whether curved or straight, between two anatomical structures in the heart that is sufficient to block a wavelet, i.e., forms a boundary for the wavelet. Anatomical structures, referred to as "atrial trigger spots," are those regions in the heart having limited or no electrical conductivity and are described in Haissaguerre et al., "Spontaneous Initiation of Atrial Fibrillation by Ectopic Beats Originating in the Pulmonary Veins," New England Journal of
20 Medicine, 339:659-666 (Sept. 3, 1998), the disclosure of which is incorporated herein by reference. The linear lesions typically have a length of from about 1 cm to about 4 cm, but can be longer or shorter as necessary for a particular procedure.

The probe described in FIGs. 1 to 3 having a long tubular electrode is particularly useful for this procedure because it can create relatively long lesions. The probe depicted in FIGs. 4 to
25 6 above, having a smaller but flexible ablation electrode, is useful if the surgeon does not want to ablate as much tissue or wants to ablate a more precise lesion. The above-described probe having a flexible body is particularly useful if the surgeon needs to have a probe that conforms to a particular site to better ablate a desired region of tissue. Additionally, the flexible electrode is particularly useful for ablating locations where it is desirable to have the electrode conform to
30 the tissue,, rather than having the tissue conform to the electrode, for example, an atrial

1 appendage. Further, the circular coil design can be used to form a generally circular region
around an orifice of a tubular structure, such as a pulmonary vein, the coronary sinus, the
superior vena cava, or the inferior vena cava. Once the heart is closed, the surgeon can use the
probe on the outside of the heart, not only to ablate, but to verify that the electrical conduction
5 has been stopped using the mapping electrodes. As would be recognized by one skilled in the
art, the probes of the present invention can be used during open heart surgery for other
procedures as well.

 The preceding description has been presented with reference to presently preferred
embodiments of the invention. Workers skilled in the art and technology to which this invention
10 pertains will appreciate that alterations and changes in the described structure may be practiced
without meaningfully departing from the principal, spirit and scope of this invention.

 Accordingly, the foregoing description should not be read as pertaining only to the
precise structures described and illustrated in the accompanying drawings, but rather should be
read consistent with and as support for the following claims which are to have their fullest and
15 fairest scope.